ARMY RESEARCH LABORATORY

Enhancement of Semiconductor Bridge Initiators for Ignition of Large-Caliber Ammunition

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13. ABSTRACT *(Maximum 200 words)*
Semiconductor bridge initiators (SCBI) have been proposed as a means of initiating the ballistic cycle in large-caliber ammunition. However, an ignition delay of more than 10 ms for a black powder basepad was not acceptable for multicomponent tank ammunition. Enhancement of the output from the SCBI was needed to reduce the ignition delay to acceptable levels. Early experiments in a small-caliber ammunition simulator suggested that if the energetic igniter material were confined around the SCBI, the ignition delay would be drastically reduced. This work presents the results obtained from a fabricated booster that, when initiated by an SCBI, reduces the ignition delay of black powder basepads to submillisecond intervals. Results obtained from replacing black powder in the basepad and/or booster with ball powder indicated that usage of ball powder is not appropriate except in the case of black powder in the booster and ball powder in the basepad. This combination provided a strong ignition stimulus with a marginal ignition delay for the basepad of about 12 ms.

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1. INTRODUCTION

Electrically initiated ammunition typically utilizes a small bridgewire to ignite subsequent primer material, pyrotechnics, or propellants. There has been a lot of research to prevent accidental activation of the bridgewire assembly when the ammunition is exposed to radio-frequency or other large-field electrical environments. One approach to surmount this problem is the use of a semiconductor bridge initiator (SCBI) as the electrical initiator component. The SCBI has demonstrated adequate resistance to these environments and has qualified as a tentative Hazards of Electromagnetic Radiation to Ordnance (HERO) igniter (Hartman and McCampbell 1992).

Earlier work has demonstrated that semiconductor bridge initiators can successfully ignite black powder (Howard, Chang, and Atkeson 1992). During a review of the data from this work, it was noted that the ignition delay times for three grades of black powder (Class 1, Class 2, and Class 3) were shorter if the black powder was ignited in the 25-mm gun simulator (chamber diameter of 34 mm) than if it was ignited in the larger diameter (76 mm) flamespread chamber. This effect was thought, in part, to be due to the proximity of the chamber walls to the black powder and to the SCBI.

After the initiation of the SCBI, the rapidly expanding gases from the SCBI ignition break open the cloth basepad, and some of the black powder is scattered, which prevents feedback of heat and pressure from burning particles to the bulk of the black powder. If the chamber walls are close about the SCBI, as in the smaller simulator, the walls reflect the expanding gases back to the area containing the black powder as well as restrict the movement of scattered black powder from the basepad; thus, a local confinement is created. In a condition of local confinement, the heat and pressure contribute to enhancing the overall burn rate.

It was also noted that smaller particle size black powder ignited faster (i.e., Class 5 powder ignites more rapidly than Class 1 powder). It was postulated that even smaller black powder grain dimensions as well as closer packing of these grains to the SCBI would further reduce the ignition delay time. These attributes were used to construct a booster to reduce the ignition delay time of basepads. Use of ball powder was also investigated.

2. EXPERIMENTAL

2.1 25-mm Simulator. The 25-mm simulator (Chang 1992) used to obtain preliminary data of black powder ignition by SCBI initiation has been described earlier, and its schematic (Figure 1) is included for comparison to the flamespread chamber.

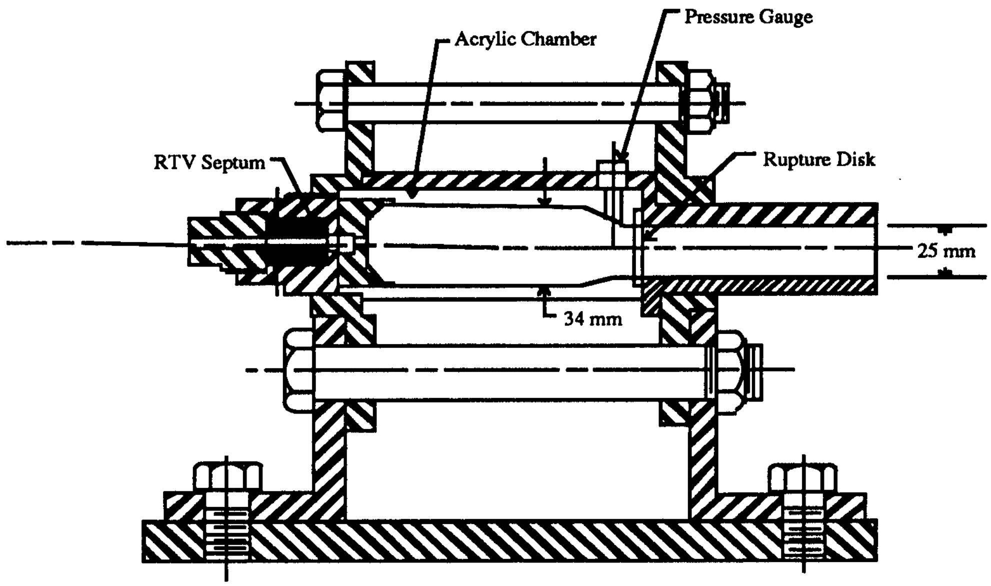

Figure 1. Cross-sectional view of 25-mm simulator.

2.2 Flamespread Chamber. The flamespread chamber (Kooker, Chang, and Howard 1992, 1994) also has been described elsewhere, and only its salient features will be discussed. The flamespread chamber (Figure 2) consisted of a transparent acrylic tube (interior diameter of 76 mm with an axial dimension of 350 mm) contained in a steel confinement casing that was designed for safety purposes to withstand pressures generated within the acrylic tube that are in excess of 70 MPa (10,000 psig). The acrylic chamber was fitted with a rupture disk rated at 21 MPa (3,000 psig). Therefore, the highest expected pressure was in the neighborhood of 21 MPa (3,000 psig). Ports were machined in the steel casing for pressure transducers. One of the pressure transducers was at the same axial position as the basepad. For these experiments, the acrylic casing was filled to within 20 mm of the top seal with inert propellant grains. The basepad containing the SCBI, the booster, and the Class 3 black powder (approximately 14 g of black powder) was then placed on the inert propellant grains. The SCBI was electrically connected to the firing line via a high-pressure electrical feedthrough in the top of the simulator.

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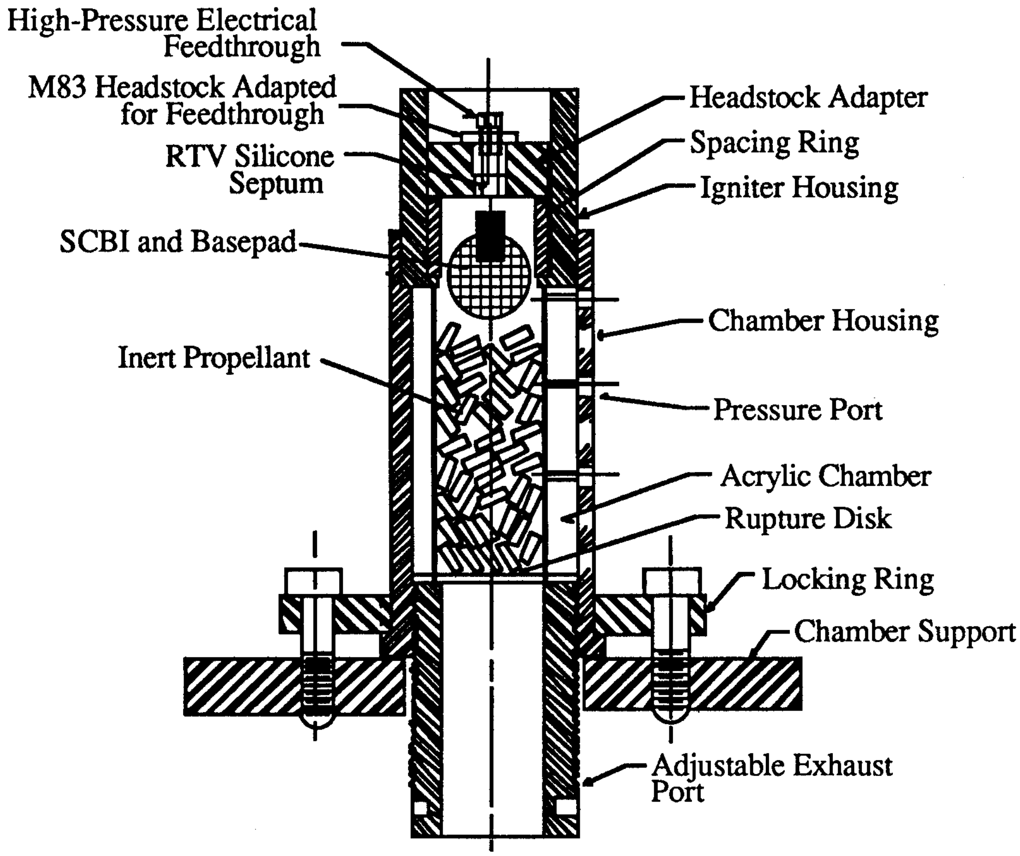

Figure 2. Cross-sectional view of flamespread simulator with SCBI and basepad.

The booster was fabricated from aluminum bar stock with interior dimensions of 12 mm by 20 mm (see Figure 3). The SCBI was glued in one end with an epoxy compound so that the active volume of the SCBI was completely within the booster volume and the base of the SCBI was securely attached to the booster body. It was desired that the SCBI base would remain in place during the ignition of the powder in the booster. The remaining booster volume was filled with approximately 2.2 g of Class 3 black powder that had been crushed to a fine powder. The booster was sealed with a thin aluminum disk held in place with more of the epoxy compound. The booster element was then placed in a cloth basepad filled with approximately 14 g of energetic material, as shown in Figure 4.

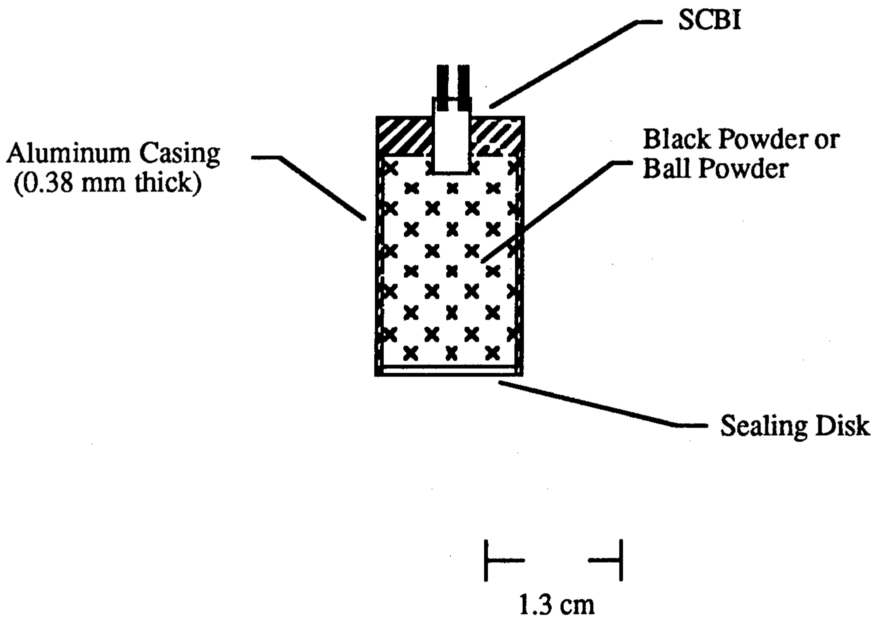

Figure 3. Cross-sectional view of booster.

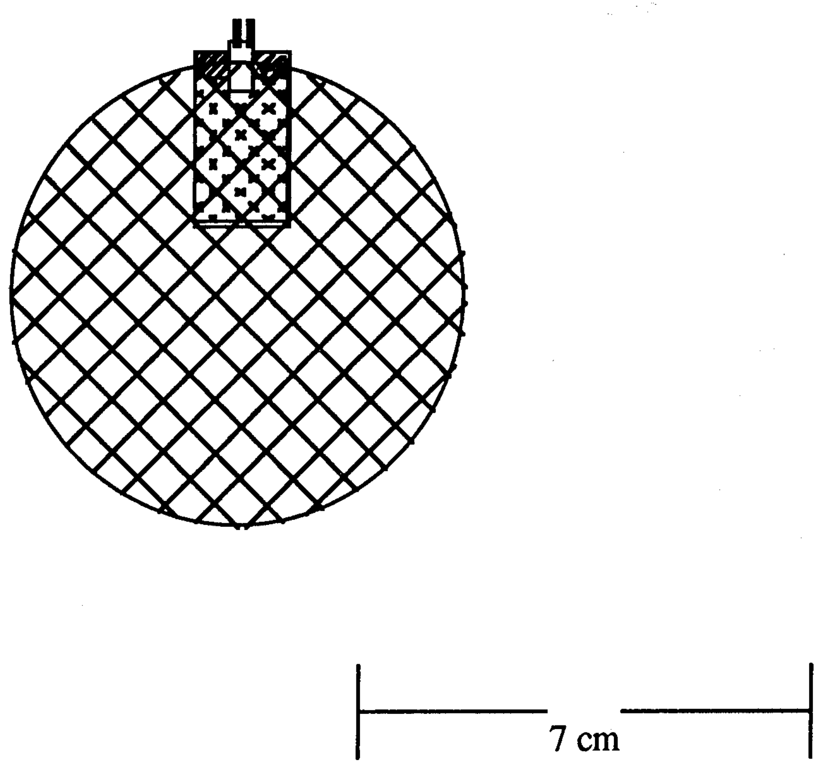

Figure 4. Cross-sectional view of booster in basepad.

3. RESULTS AND DISCUSSION

3.1 Preliminary Ignition Delay Data for Black Powder. Earlier results of ignition of black powder in the 25-mm simulator demonstrated ignition delay times (ignition delay time defined as the amount of time required to double the pressure output from the SCBI) that were acceptable for tank ammunition. For these tests, a small cloth bag was constructed with 1.1 g of black powder placed in each bag. For Class 3 black powder, an ignition delay time of 2 ms (Figure 5) was observed, and for Class 5 black powder, a delay of approximately 1.8 ms (Figure 6) was observed.

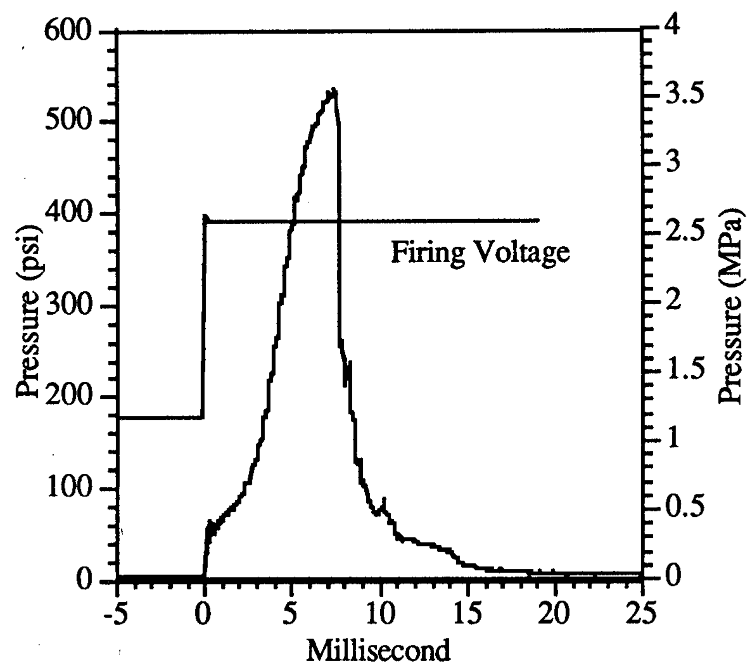

Figure 5. Pressure curve for Class 3 black powder ignition by SCBI in 25-mm simulator.

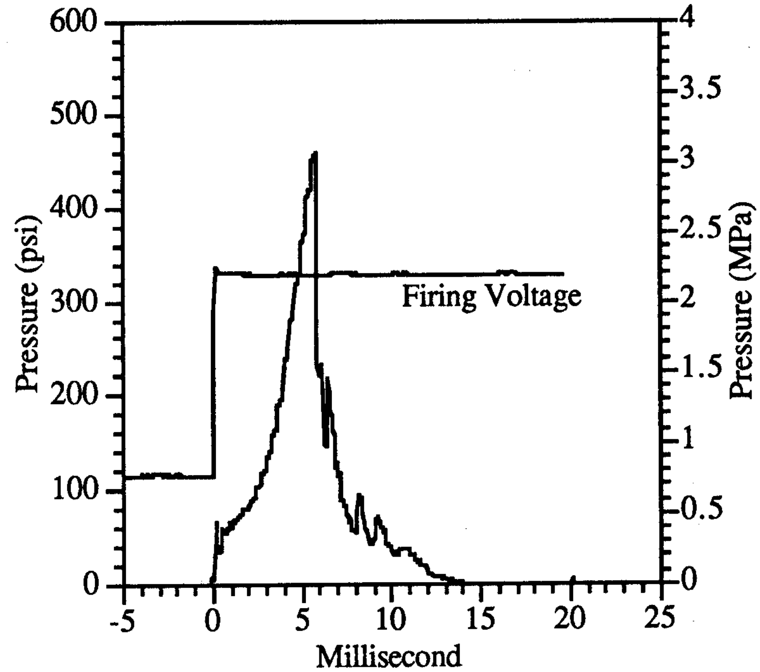

Figure 6. Pressure curve for Class 5 black powder ignition by SCBI in 25-mm simulator.

However, in the larger flamespread chamber, Class 3 black powder demonstrated (Figure 7) an ignition delay time of approximately 20 ms. Several factors contributed to this long delay with respect to that in the 25-mm simulator. Most important was the confinement of the black powder. In the 25-mm simulator, the simulator walls were close to the basepad and hot gases formed in the basepad by the burning black powder remained in the immediate vicinity of the basepad. The confinement permitted thermal feedback from the hot gases into the black powder remaining in the basepad, as well as a higher pressure. The higher pressure created a higher density in the gases that also increased the thermal feedback.

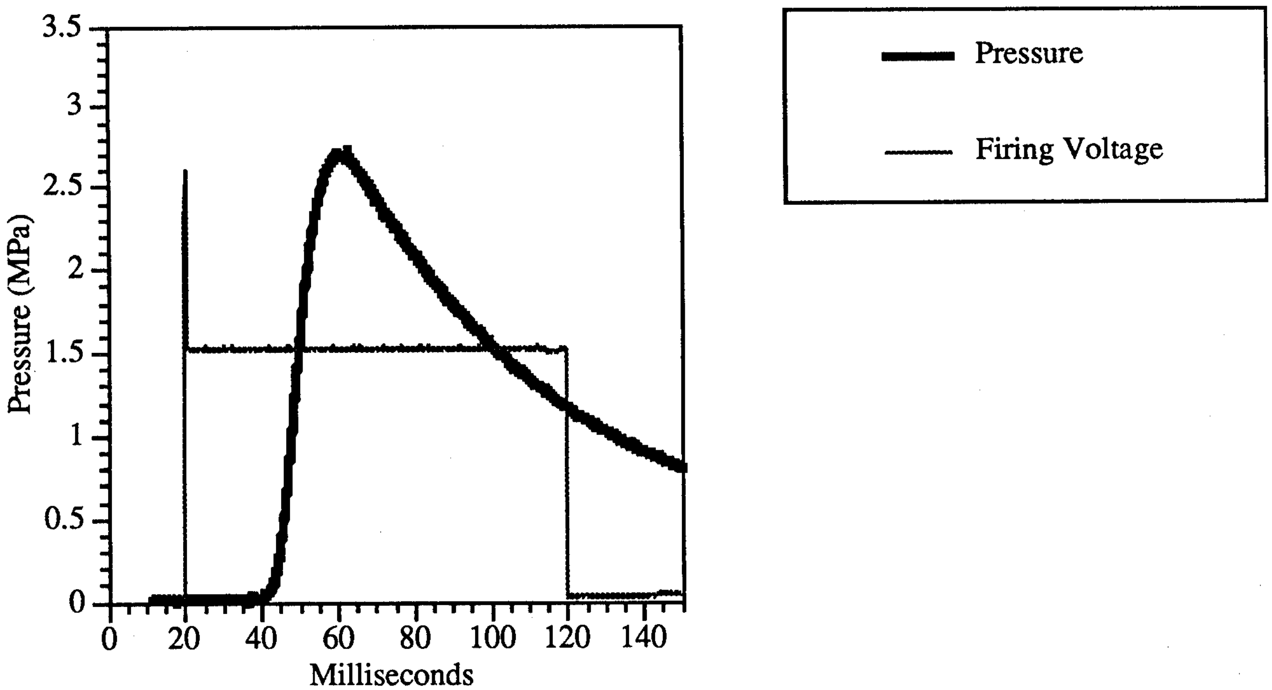

Figure 7. Pressure curve for Class 3 black powder ignition by SCBI in flamespread chamber.

In the flamespread chamber, the walls were further away and the hot gases formed in the basepad could escape into the greater chamber volume and not remain as long within the basepad. This effect reduced the thermal feedback to the remaining black powder and increased the ignition delay. For tank ammunition, this amount of ignition delay time of the igniter alone is not acceptable. The total ignition delay time will be even longer in the completed round since an ignition delay time for the propellant also exists. The ammunition is also of larger diameter than the flamespread chamber, and the same factors that increased the ignition delay time in the flamespread chamber over that in the 25-mm simulator will increase the time over that observed in the flamespread chamber. Hopefully, a fast-burning booster material confined in close proximity to the SCBI would significantly decrease the ignition delay time of the igniter. Therefore, the booster concept was attempted.

3.2 Booster Test Matrix. Since there is interest in replacing black powder in ammunition, experiments were also conducted with an available ball powder (Winchester 748 propellant, Lot number 748066BF6A). The following test matrix was created that utilized black powder and ball powder in both boosters and basepads:

- Solitary SCBI in a black powder basepad,
- Solitary SCBI in a ball powder basepad,
- Black powder booster in a black powder basepad,
- Black powder booster in a ball powder basepad,
- Ball powder booster in a black powder basepad,
- Ball powder booster in a ball powder basepad.

Both black powder and ball powder boosters contained approximately 2.2 g active material in addition to an SCBI. They were used to ignite basepads (approximately 14 g of energetic material). All experiments were conducted in the flamespread chamber.

3.2.1 Solitary SCBI in Basepad. The case of the solitary SCBI within a black powder basepad was discussed in Section 3.1 with an ignition delay of approximately 20 ms. However, the solitary SCBI in a ball powder basepad had a completely different result. In Figure 8, it looks as if nothing happened. On close examination (Figure 9), the pressure resulting from the SCBI ignition is evident with an ignition delay less than approximately 0.5 ms. Any ignition of the ball powder was insignificant and rapidly quenched. At this higher resolution a 270-Hz noise signal is obvious.

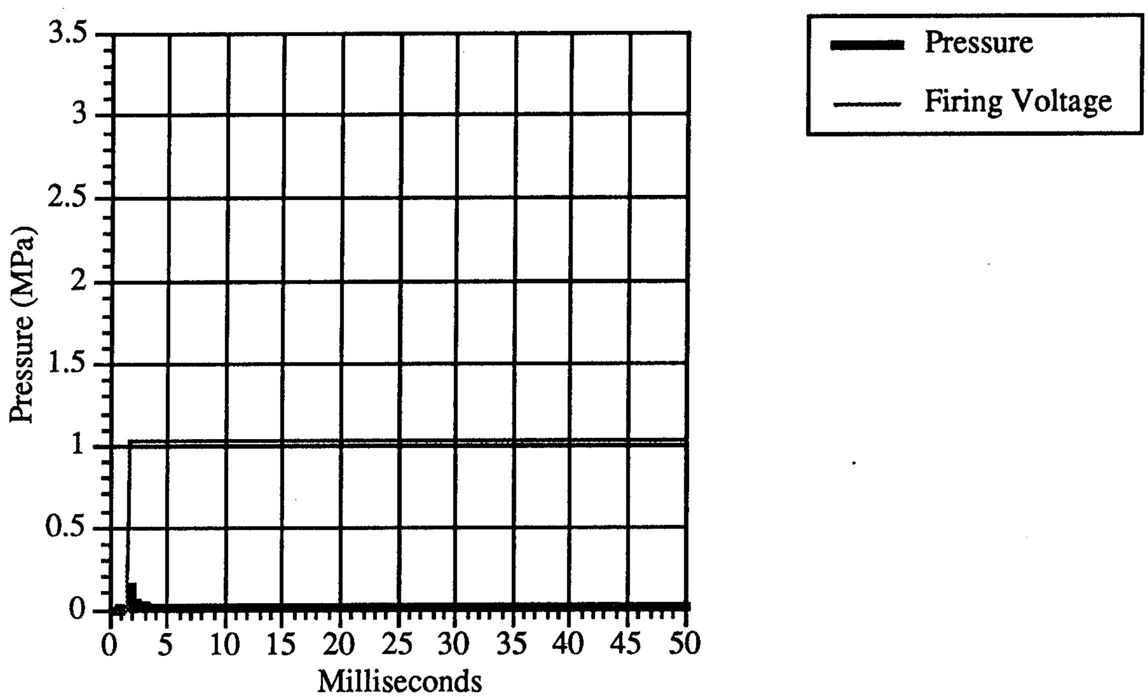

Figure 8. Pressure curve of solitary SCBI in ball powder basepad.

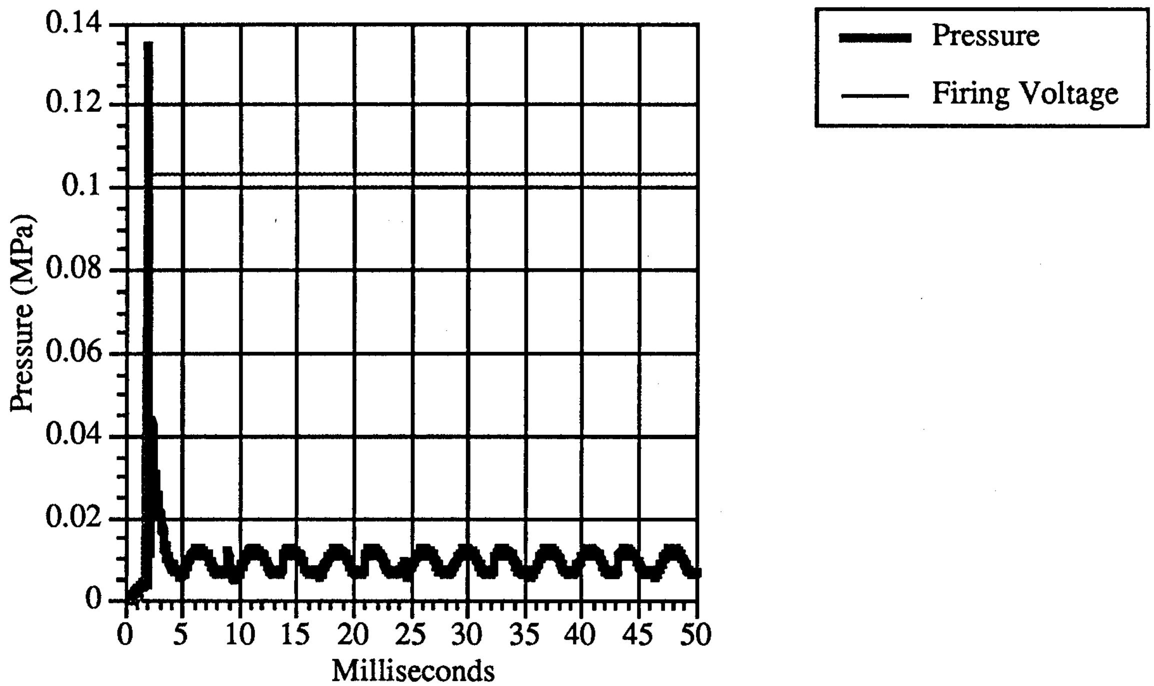

Figure 9. Expanded pressure curve for solitary SCBI in ball powder basepad.

3.2.2 Black Powder Boosters. The boosters containing black powder operated much better than the solitary SCBI. Figure 10 shows the pressure curve of a black powder basepad ignited by a black powder booster. The pressure rise occurs immediately upon application of the firing voltage, and the pressure gradient is steep, indicating a rapid ignition of the entire basepad (approximately 1 ms to maximum pressure). Figure 11 is a closeup of the initial ignition. The SCBI required approximately 0.1 ms for initiation followed by a slight reduction in pressure as the black powder in the booster began to ignite. This period was then followed by a large pressure rise as the basepad subsequently ignited. The ignition delay for Class 3 black powder in the basepad was approximately 0.35 ms. This time is well within the ignition delay time variance of standard igniters such as the M83 headstock.

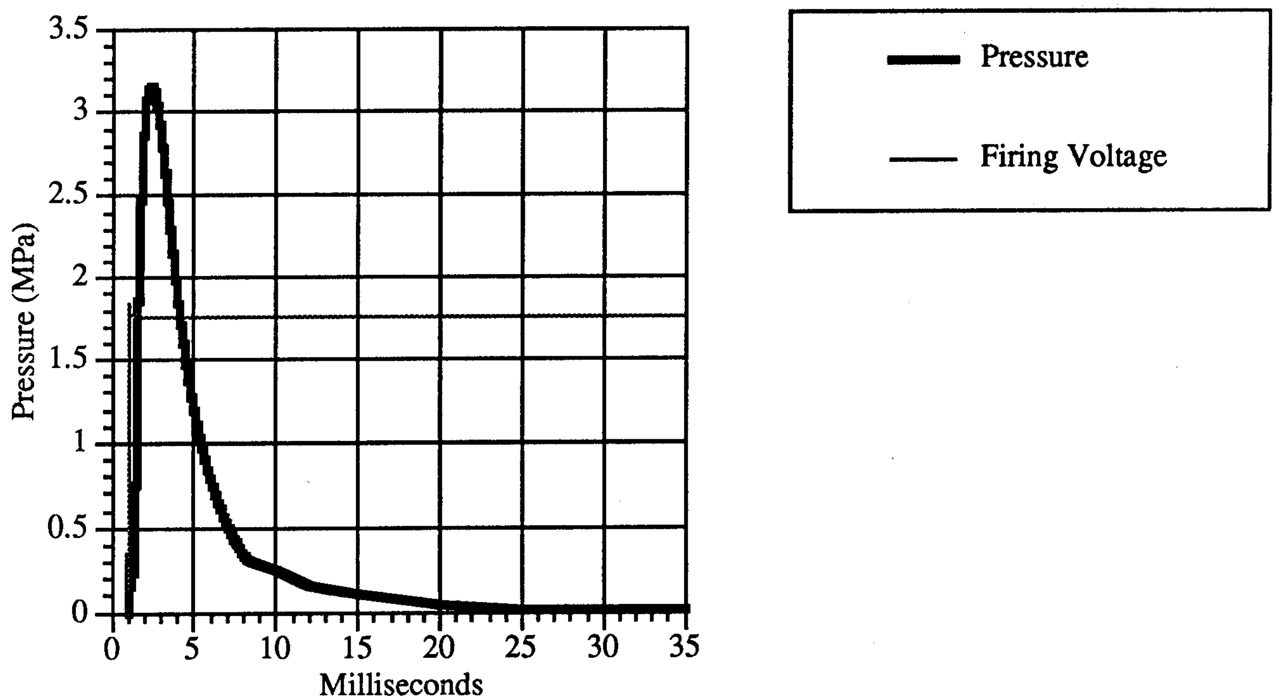

Figure 10. Pressure curve of black powder booster in black powder basepad.

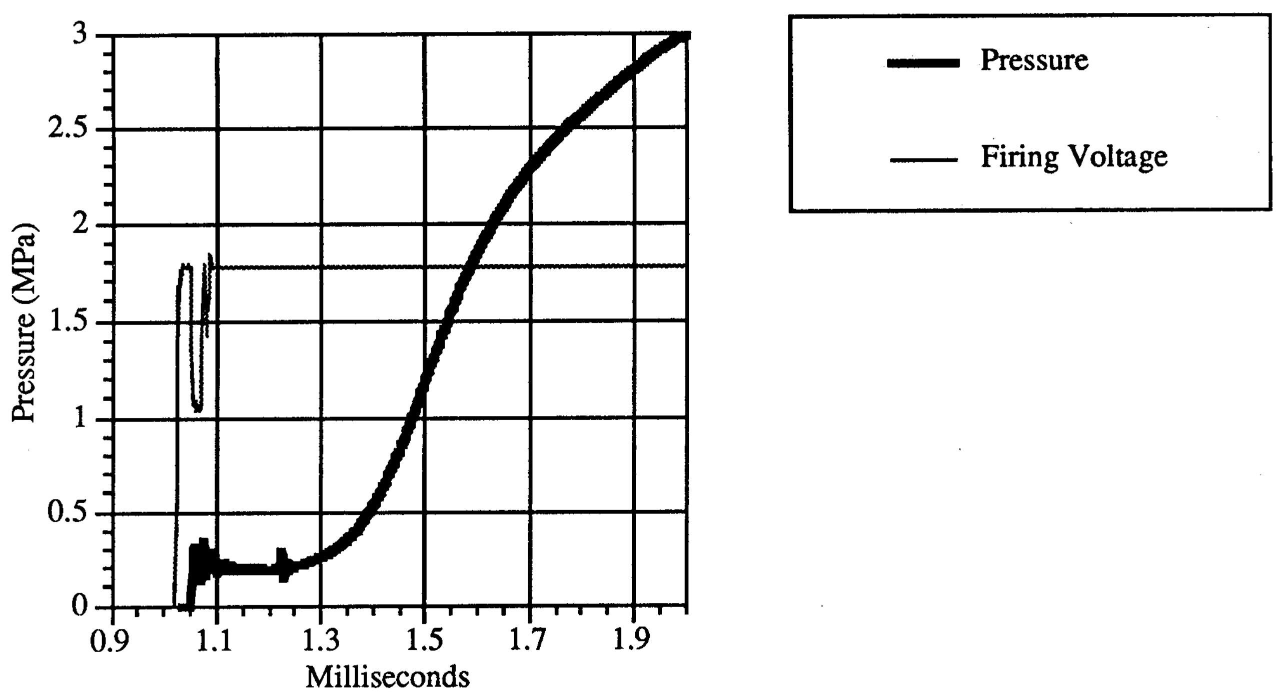

Figure 11. Expanded pressure curve for black powder booster in black powder basepad.

When the black powder basepad was replaced with one containing ball powder, the ignition delay time increased as may have been anticipated by the solitary SCBI results. The ball powder is harder to ignite than black powder. In Figure 12, the ignition and rupture of the black powder booster occurred in less than a millisecond. The bulk of the black powder from the booster then was dispersed into the basepad. This black powder continued to burn until its maximum pressure occurred approximately 6 ms after the SCBI ignition. The gases then began to cool and the pressure dropped. Approximately 10 ms after SCBI ignition, the ball powder began to burn as evidenced by the increase in pressure. The maximum pressure was obtained about 10 ms later. Ignition of the ball powder basepad ultimately provided a more vigorous ignition source than the black powder basepad. This item in the matrix was the only one that ruptured the blowout disk, an 18-mm-thick acrylic plate. Therefore, more gases at higher pressures were generated than for the essentially equivalent mass of black powder. However, ball powder does not have as great a low-pressure burn rate as black powder, and more time is required for effective ignition. Therefore, if an ignition delay time of several milliseconds is not an issue, this configuration may provide a better igniter combination than a black powder booster with a black powder basepad.

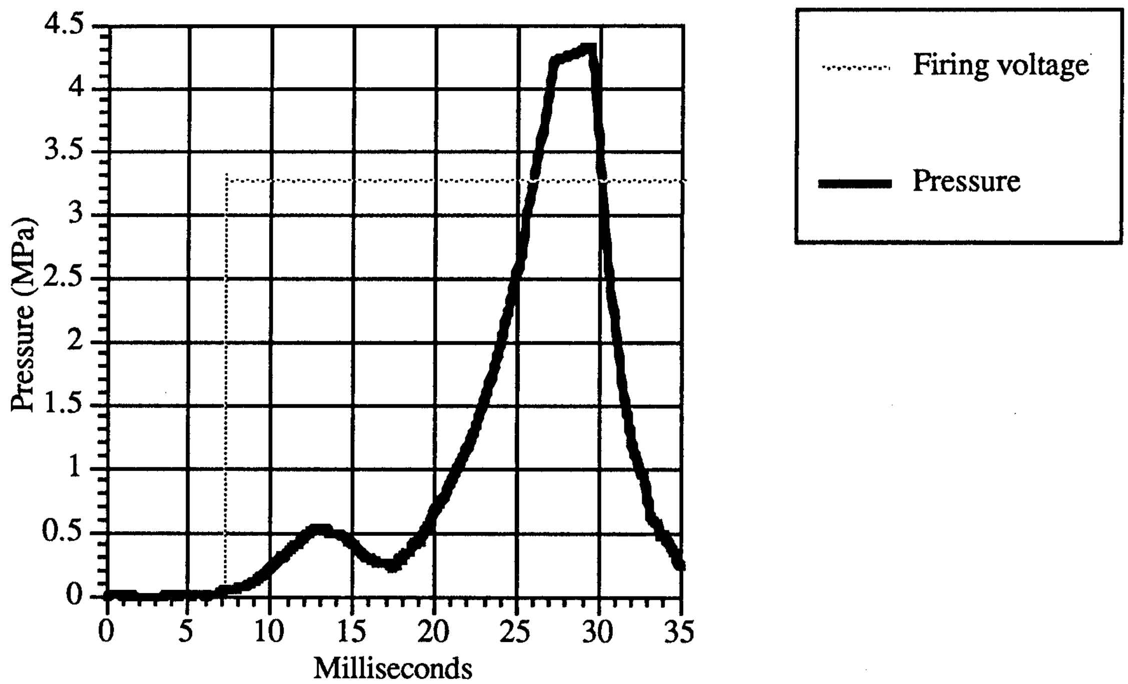

Figure 12. Pressure curve for black powder booster in ball powder basepad.

3.2.3 Ball Powder Boosters. The pressure data obtained from the ball powder boosters are represented by Figures 13 to 15, respectively. For all three test cases, the ball powder booster did rupture upon ignition. Since the pressure pulse in Figures 13 and 14 was approximately three times that of the solitary SCBI, it was supposed that some ignition of the ball powder in the booster did occur. However, the gases and/or the force of the rupturing booster walls only blew apart the basepad and scattered ball powder throughout the chamber. No visible evidence of ball powder ignition was observed.

Further evidence for some ignition in the ball powder booster is shown in Figure 15. For this case, the booster ruptured and the pressure rose to over 1.5 MPa. However, the ignition delay time of the black powder in the basepad was greater than 3 ms. Maximum pressure was attained in approximately 20 ms. This result indicated that even if the rupturing booster did blow apart the black powder basepad, residual gases were hot enough to be an ignition source for the black powder. However, this ignition source was quite weak and did not provide an adequate ignition source for even black powder.

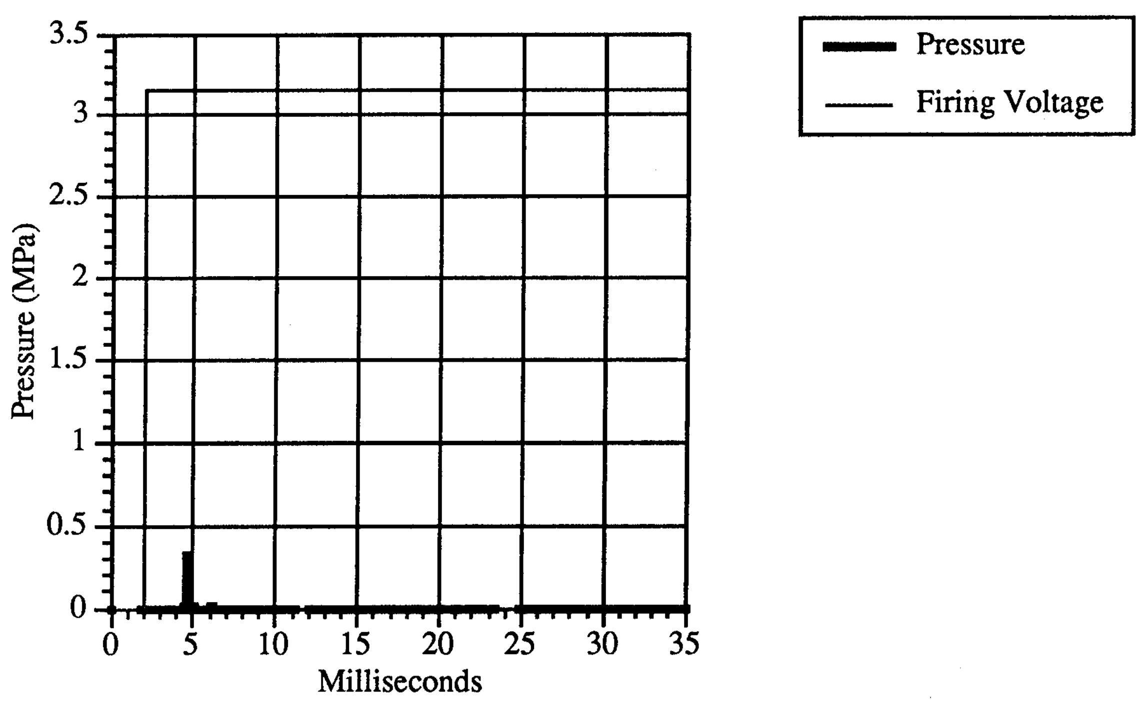

Figure 13. Ball powder booster in ball powder basepad.

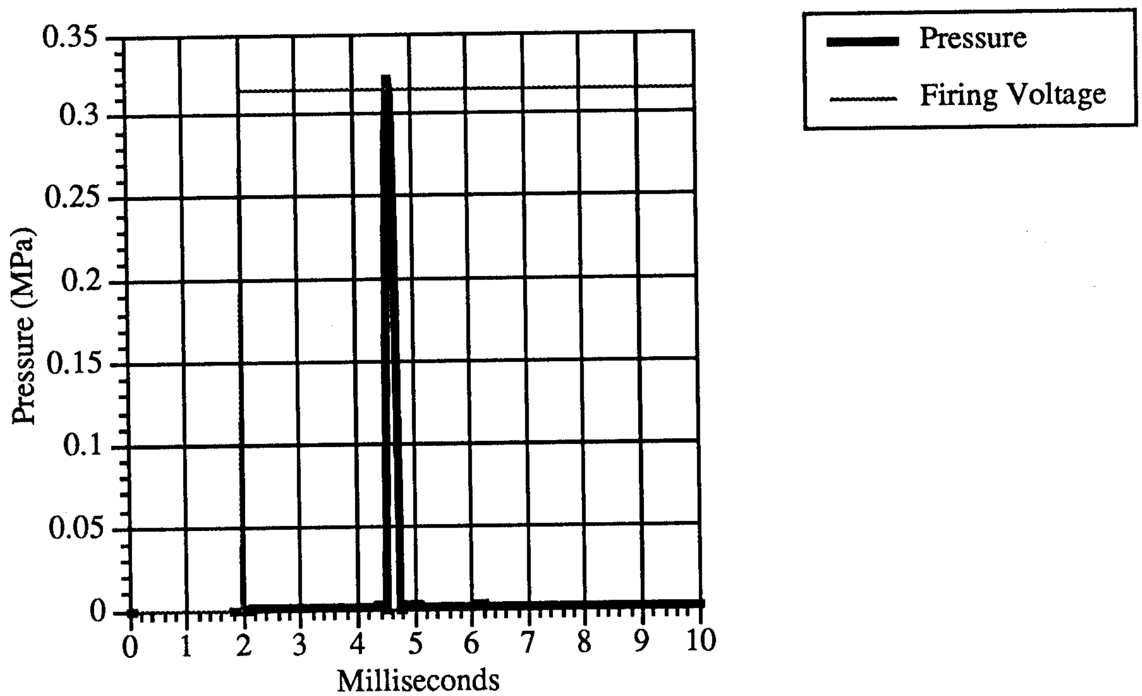

Figure 14. Expanded pressure curve for ball powder booster in ball powder basepad.

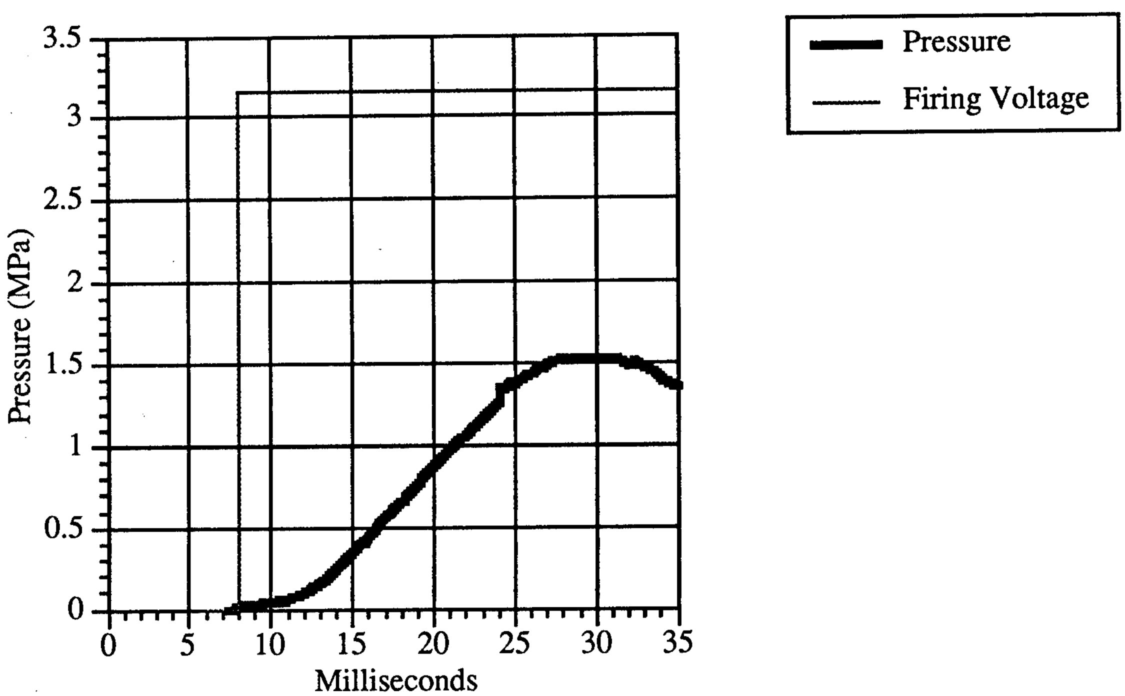

Figure 15. Pressure curve of ball powder booster in black powder basepad.

4. SUMMARY

The following table summarizes the results of the test matrix in this study:

SCBI	Ball Powder	Black Powder	Ignition Delay (ms)	Pressure (MPa)
Yes	Basepad		No Ignition	
Yes		Basepad	20	2.8
Yes	Booster/Basepad		No Ignition	
Yes	Booster	Basepad	5	1.5
Yes	Basepad	Booster	12	>4.3
Yes		Booster/Basepad	0.4	3.2

Placement of energetic material in close proximity to an SCBI in the form of a booster increases the output of the SCBI. Fine black powder provides a rapid and adequate ignition source for subsequent igniter material (both black powder and ball powder). Ignition delay time of a Class 3 black powder basepad can be reduced to several tenths of a millisecond.

Ball powder does not provide an adequate booster material for SCBI initiators. However, the combination of a black powder booster with a ball powder basepad could provide a good ignition source for subsequent propellant ignition. This combination could be even better than a black powder booster with a Class 3 black powder basepad if the ignition delay time of several milliseconds in addition to the time required for propellant ignition is acceptable.

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